Claims

1. A method for determining components of a tube casing surrounding a tube, using amplitude measurements of an acoustic signal wavefront emitted inside the tube, the acoustic signal wavefront being affected by the components of the tube casing while propagating in the tube the method comprising

- Determining an attenuation A(E) of the amplitude inside the tube,
- Determining a percentage of cement bonded ϕ_C in the tube casing, a percentage of cement de-bonded ϕ_D in the tube casing and a percentage of liquid ϕ_W in the tube casing, by inverting the following equations :
  - $A(E) = \phi_C * A(E_{fc}) + \phi_W * A(E_{fp}) + \phi_D * A(E_{fd})$
  - $\log E_{P1} = \phi_C * \log E_{P1,fc} + \phi_W * \log E_{P1,fp} + \phi_D * \log E_{P1,fd}$
  - $\phi_C + \phi_W + \phi_D = 1$

  wherein E_{P1} is the amplitude measured at a location P1, $E_{P1,fp}$ is the amplitude at the location P1 for a free-pipe tube casing, $E_{P1,fc}$ is the amplitude at the location P1 for a fully cemented tube casing, $E_{P1,fd}$ is the amplitude at the location P1 for a fully de-bonded tube casing, and $A(E_{fp})$, $A(E_{fc})$, $A(E_{fd})$ being the attenuations of amplitude in case the tube casing is respectively free-pipe, fully cemented, and fully de-bonded.

2. A method for determining components of a tube casing surrounding a tube, using amplitude measurements of an acoustic signal wavefront emitted inside the tube, the acoustic signal wavefront being affected by the components of the tube casing while propagating in the tube, the method comprising

- Determining a coupling Amplitude E_o by extrapolating amplitude measurements made at various locations in the tube to a location of a source of the acoustic signal,
- Determining a percentage of cement bonded ϕ_C in the tube casing, a percentage of cement de-bonded ϕ_D in the tube casing and a percentage of liquid ϕ_W in the tube casing, by inverting the following equations :

- $\log E_{P1} = \phi_C * \log E_{P1,fc} + \phi_W * \log E_{P1,fp} + \phi_D * \log E_{P1,fd}$
- $\log E_0 = \phi_C * \log E_{0,fc} + \phi_W * \log E_{0,fp} + \phi_D * \log E_{0,fd}$
- $\phi_C + \phi_W + \phi_D = 1$

wherein E_{P1} is the amplitude measured at a location P1, $E_{P1,fp}$ is the amplitude at the location P1 for a free-pipe tube casing, $E_{P1,fc}$ is the amplitude at the location P1 for a fully cemented tube casing, $E_{P1,fd}$ is the amplitude at the location P1 for a fully de-bonded tube casing,. $E_{0,fp}$ is the coupling amplitude for a free-pipe tube casing, $E_{0,fc}$ is the coupling amplitude for a fully cemented tube casing, $E_{0,fd}$ is the coupling amplitude for a fully de-bonded tube casing.

3. A method for determining components of a tube casing surrounding a tube, using amplitude measurements of an acoustic signal wavefront emitted inside the tube, the acoustic signal wavefront being affected by the components of the tube casing while propagating in the tube, the method comprising

- Determining an attenuation A(E) of the amplitude inside the tube,
- Determining a coupling Amplitude E_o by extrapolating amplitude measurements made at various locations in the tube to a location of a source of the acoustic signal,
- Determining a percentage of cement bonded ϕ_C in the tube casing, a percentage of cement de-bonded ϕ_D in the tube casing and a percentage of liquid ϕ_W in the tube casing, by inverting the following equations :
  - $\log E_0 = \phi_C * \log E_{0,fc} + \phi_W * \log E_{0,fp} + \phi_D * \log E_{0,fd}$
  - $A(E) = \phi_C * A(E_{fc}) + \phi_W * A(E_{fp}) + \phi_D * A(E_{fd})$
  - $\phi_C + \phi_W + \phi_O = 1$

wherein $A(E_{fp})$, $A(E_{fc})$, $A(E_{fd})$ correspond respectively to the attenuations of amplitude in case the tube casing is free-pipe, fully cemented, and fully debonded, and $E_{0,fp}$ is the coupling amplitude for a free pipe tube casing, $E_{0,fc}$ is the coupling

amplitude for a fully cemented tube casing, $E_{0,fd}$ is the coupling amplitude for a fully de-bonded tube casing.

4. The method according to anyone of claims 2 to 3, wherein determining the coupling amplitude E_o further comprises

- Defining a linear function $E(X) = A * X + E_o$ in which an amplitude $E(X)$ of an acoustic signal wavefront measured at a location X in the tube is subject to an attenuation A, and
- Calculating $E(X) = E(0)$ for a location where X=0, corresponding to a source of the acoustic signal in the tube.